Salt Flats

United States Department of the Interior

BUREAU OF LAND MANAGEMENT
Salt Lake District Office
2370 South 2300 West
Salt Lake City, Utah 84119

TAKE PRIDE IN AMERICA

IN REPLY REFER TO:
7000
(UT-022)

Deb - this was moved to Nov. 17 9-12am

Dr. Dianne Nielson
Director, Utah Department of Environmental Quality
168 North 1950 West
P.O.Box 144810
Salt Lake City, Utah 84114-4810

Dear Dianne:

Thank you for your participation in the last meeting of the Technical Review committee. I have enclosed a copy of the minutes for your review. I have also copies of the overheads used by the U.S.G.S. to be included with their quarterly report.

The next meeting of the Technical Review Committee is scheduled for October 20, 1993 at 9:00 a.m. Ken Kipp may have a conflict with this date. If this does happen, we have scheduled November 17, 1993 as an alternative date. Please save this time on your calendar.

I appreciate all the efforts of each member of the committee, even those of you who have had to miss a few meetings. The TRC has been instrumental in keeping this study on track. I look forward to seeing you at the next meeting.

Sincerely,

Deane

Deane H. Zeller
District Manager

Enclosures
As Stated Above

Minutes of the Technical Review Committee
Pre and Post Meetings of July 28, 1993
Recorded by Philip Allard

Attendance:

Committee Members:
Paul Anderson (PA)
Craig Forster (CF)
Jim Kohler (JK)
Stanley Plaiser (SP)
Ton Netelbeek (TN)

BLM Representatives:
Phil Allard (PhA)
Mike Ford (MF)
Doug Koza (DK)

U.S.G.S. Representatives:
Jim Mason (JM)
Lee Case (LC)
Ken Kipp (KK)

Premeeting

The premeeting began at 9:10 am in the Salt Lake District conference room. The representatives from the USGS were not present.

1. PA introduced the minutes from the 5/5/93 meeting. PA moved to approve them as written. CF seconded the motion and all members present voted to approve. PA then introduced the corrected minutes of the 2/2/93 and the 2/23/93 meetings. PA moved that they be approved as written. TN seconded the motion and all members present voted to approve.

2. PA then introduced the USGS progress report for discussion. PA said that he was concerned about the approach used to analyze the potential redistribution of salt. He was concerned that the elevation of the casings could have changed which could be a source of error. CF said that the only way to be certain that the casing had not moved over the winter was if you had elevation survey both before and after the winter. JK indicated that he would even concerned about the deep wells. CF said that it was reasonable to assume that some movement of the casing could have occurred. PhA said that an elevation survey of the casings was scheduled for late August. TN questioned if there really would have been significant changes to the elevation of the casings. PA said that he didn't know but he felt that this could be a potential source of error in the analysis and wanted to be sure that the USGS had considered it. PA suggested that this concern be raised with the USGS.

3. TN said that he was concerned about the satellite imagery. He was concerned that USGS was not ordering a scene from fall of 91 solely because of lack of funds. TN suggested that this scene could be important. CF asked if there was a need to get fall of 91 and spring of 92. PA said that this was a good idea. CF said 92 fall was important because of the better ground truth than the first season of the study. JK said that the were probably selecting the scene they were because they have seen new salt crust. PA said that if they were to use satellites in calibrating the model than additional satellite data may be needed. PA said that TN should be sure to get clarification from the USGS on this issue.

4. PA said that he was not clear on the need to have the salt surface dry before they sampled the water from the wells. He said that he planned to ask about this.

5. JK said that he was concerned about the statement about there was no apparent recharge of the K to the aquifer yet at the same time you have no depletion of K from the aquifer due to mining. SP said that the May data might be able to clarify this. PA said that the third paragraph on page 3 (discussion of dual porosity) may be related to this. PA said a similar explanation as presented here may explain the K phenomenon. SP was concerned that the cores for the pore fluids may not have been from the same interval as is yielding to wells. JK observed that K appeared to be a renewable resource.

6. TN was surprised that the USGS is saying that the computer modeling has not been successful, yet is was sold as the key element of the study. CF said that this was a classic situation with models. The modeling effort appears to be behind schedule. CF said that some of these issues are surmountable but it is not clear that there is the time to do this. TN said that this may be something to pass on to Deane.

At 9:30 the premeeting concluded and the USGS were invited to join the meeting.

Post Meeting

1. PA asked about the status of the density survey. PhA said that it was planned for early September and that a density meter would be used. PA asked how it would be calibrated PhA said that it would be calibrated in the surface salt. PA suggested this may not be sufficient and requested that the TRC be contacted to discuss the details over the phone when it was ready to run.

2. PA spoke briefly about the confidentiality issue and about the status of the Environmental Assessment for the salt laydown project.

3. TN had a question about the modeling. If the cross sectional models are to be part of the report he was concerned because they didn't look like how he understood the system. TN pointed out that KK had said he only spends 25% of his time on this project. TN asked how much modeling was yet to be done? How much can be done with the funds that are remaining in the study.

4. It was the consensus of the members of the TRC present that the are concerned about the progress of the computer modeling. They are concerned that the model that will be produced may be substantially less than that in the original proposal. They recommended that Deane Zeller discuss this issue with Lee Case.

5. The last item discussed was the role of the TRC after the study was completed. The question was raised as to a continuing role for the TRC. The issue was discussed but not resolved.

Minutes of the Technical Review Committee
Meeting of July 28, 1993
Recorded by Philip Allard

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Committee Members:
Paul Anderson (PA)
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U.S.G.S. Representatives:
Jim Mason (JM)
Lee Case (LC)
Ken Kipp (KK)

1. PA welcomed the USGS people and turned the meeting over to JM. JM started with slides. The first slide showed a large flow of water through culverts in the freeway from south to north. This was from the third week in May 93. It showed 19 new culverts in the freeway. This flow started in February or March. The density of the water at this point was about 1.04. Then he showed the weather station underwater on the May 21 sampling run to look at vertical circulation. Then he showed a slide of flow through a breach in the Salduro dike at the north end of the dike. This is one of two or three breaches through which brine moved. At this point the water was near saturation. This indicates that the fluids picked up salt from the area within the salduro loop and deposited it out on the northern portion of the salt flats. JM then showed a picture of another set of culverts. JM said the source of this water was precipitation, and the salt redistribution from this spring and summer may be an analog of the proposed salt laydown project. JM then showed a picture of the piping on the Silver Island alluvial fan. JM then showed pictures taken in early July. From the north end of the raceway you can see salt to the horizon. He showed a slide from the same area in 92 which showed a salt surface broken by pressure ridges. The new salt surface is bumpy in places. JM then showed new salt immediately adjacent to the collection ditch which they measured to be .15 inches thick.

2. JM then started a discussion of the progress report. JM said that they had instrumented wells on the alluvial fan near the interface with vegetation. They had not yet reduced the data from the data logger. CF asked if there were any generalities that could be made by looking at the data. JM said he did see a change in elevation of the ground water surface on June 20 but there was

no obvious diurnal variation. JM said that the data logger was recording every four hours. CF asked if they could record more frequently, for example once per hour. JM said that they would consider this, but that once every 4 hours should be sufficient. He said that one recorder was placed in vegetation and one was placed in the mud flats.

3. JM then showed a map that indicated the location of the pond. One run was made on 5/24 and the other was made on 6/15. The map was compiled by mounting a GPS unit on the back of a four wheeler and then driving around the circumference of the pond. During the 5/24 run there was a south wind that influenced the shape of the pond.

4. JM said that during water level measurements they take the measurement from the top of the casing to the top of the salt surface. They produced a contour map from these measurements from the March-April water level data run. They compared this to the previous reference points from the fall. This past winter is probably an extreme case, the wet end point of weather variation. This winter would show the kind of salt distribution that occurs during the wet end point. They know how much precipitation there was. They can estimate the amount of salt removed from areas that lost salt as measured at the casing. They can use this estimate to develop an estimate of the amount of water that entered from the south (moving a certain amount of salt requires a certain amount of water), and, since they know the salinity of the water that entered from the south, they can then estimate the amount of new salt brought from the south. This is a mass balance approach to making this estimate. PA said that this assumes that no salt goes into the shallow brine aquifer. JM said that this was true and that they were looking at various sources of error, but that this approach will generate an estimate. JM also said that casings could also move, and in wells completed with votclay(?) grout this was more likely because the grout had not adhered well to the side of the hole. CF asked if they were planning new wells. JM said no. He also said that the ten new wells that they augured had the casings packed with backfilled cuttings. PA said that the he was also concerned that the casings may have moved and asked how the USGS was thinking of isolating this error. JM said that the only way to pin this down would be to survey the elevation of the top of the casing and that this had been scheduled with the BLM. JM said that he would like to measure the elevation on all of the wells; some of the wells already have elevations, so they should be able to tell if these moved. This will give a good feel for how significant casing movement may be. MF asked is salt gain was in any way related to topography. JM said no. This is because the areas of salt gain are to the east, and the topographic low is on the west side of the salt flat, away from the salt gain area.

5. JM said that they hand augured a series of wells near the collection ditch. They observed that they had little water enter the bore hole in the first 2 to 3 feet, but after this depth water rapidly entered the bore hole. JM said he felt that this indicated

that the fractured controlled aquifer doesn't extend to the surface. He said that there is tighter material at the surface than at depth. CF suggested that there is also an alternative explanation. Perhaps the material at the surface has had more diagenesis than the material at depth and the lower material has intergranular rather than fracture flow. JM said that his point was that there is probably little infiltration from the ponded water into the shallow brine aquifer in this area of the mud flat. JM asked CF if he had evidence to support his proposal. CF said he hadn't followed it up but is suggesting that there is more than one hypothesis available. PA asked if JM was suggesting that the fractures in the shallow brine aquifer aren't in contact with the base of the salt crust. JM said that he was not suggesting that the same conditions exist under the thick salt crust. It is only in the area near the collection ditches where this has been observed.

6. JM then showed overheads (attached to minutes) that listed provisional chemistry of surface water and shallow well water. TDS was the same but there were differences particularly in K and Mg concentration and isotope ratios. JM said that he still questions if there will be mixing of these waters as the year progresses. They should be able to identify this should they see changes in the chemistry of the shallow brine. This is also a way to approach the questions of circulation in the shallow brine.

7. TN asked about the use of satellite data. He said that originally it had been proposed to have a scene from the fall of 91. In the quarterly report it says the scene from 91 wasn't to be acquired unless it is found that the data will be useful. TN said he didn't understand why fall 91 wasn't to be acquired especially since 91-92 was a more normal year than 92-93. JM said that there were several reasons for this. They have little data for use in ground truthing the 91-92 period; there was little change in the salt crust between fall and spring 91-92; and finally each scene costs $3,100 for just the data, which doesn't include any data processing. JM said that admittedly things change throughout a study like this one. The pond migration issue has been the most difficult to get under control. At this point it appears that the best potential for results is in the chemistry data.

8. JM then discussed the long term trends in K data. 81 data indicate depletion of K but there is the possibility that this is a seasonal variation related to mixing of the shallow brine with K depleted waters (precipitation). The specific gravity of the waters is the same but the K values are depleted in the May 81 data set when compared to both the 66 and 92 data sets. Both the 66 and 92 data sets are late summer/fall data collections. PA asked if JM had any suggestions as to mechanism for this. JM suggested that surface pond water is depleted with regard to K and MG because the ponds pick up their salts by dissolving the NaCl rich crust. In a year with little precipitation you get ponds from ground water rise and may see no change in chemistry. In large precipitation years you get a pond that is depleted in regard to K. These pond waters

then mix with the shallow brine. JM suggested that they need to see if they can find any information on the pond during the 80-81 winter. Either rainfall data or satellite images would be helpful.

9. CF commented on sampling strategies. He asked what pumping were they referring to in the discussion of sampling in the quarterly report. JM said they were referring to pumping the wells during the sampling process. They need the surface to be dry so that they do not pump surface water into the well. With the surface dry they can be assured that they are getting a sample of the shallow ground water and not a sample of the surface pond.

10. JM said that this summer they will be looking at collecting tritium data. Precipitation values for tritium are now at 11 units. Low numbers (he got 4 last year) could indicate upward leakage into the system of pre-bomb waters. The tritium sampling is going to be of limited extent because of the cost of sample processing. The most important use of tritium data is to identify any potential recharge to the shallow brine aquifer from upward flow from the basin fill aquifer. CF asked when they expect to get results from the lab. JM said that they plan to have all their samples collected by the third week of August. The lab is presently able to process this quickly, but this could change because many offices in the agency wait until the sample cut off at the end of the fiscal year to submit samples. JM wishes to wait as late into the year as possible to allow the maximum time for the aquifer to stabilize after any mixing from the pond.

11. JM said that the Cl/Br data are a good line of evidence for a dual porosity system. CF asked if the well fluids were depleted with Br as a reaction time thing. JM suggested that reason for the Cl/Br analyses was to try and establish a mechanism for the recharge of K to the system. This could be caused by the slow diffusion of K from pore fluids to fracture fluids. CF suggested that this could be verified by an experiment where cores were leached with distilled water. LC pointed out that they need to be careful what they ask for because Blair Jones, who did the work on Cl/Br, has provided a substantial amount of data without cost to the study. PA asked if there were other hypotheses out there to explain the recharge of K. JM said no others are out there at this time. JM suggested that the only other simple idea available would be from vertical rise of K rich waters from the basin fill aquifer. CF asked if there were chemical data from depth to support this. JM said he would have to look at the data. He said the ratios of the different elements were more significant than the absolute concentrations.

12. JM then reviewed the items planned for this quarter. Data collection will be completed by the end of September. LC said they are starting to work on drafting the report. JM said there is a lot of interpretation to be done and they don't yet have elevation data from the BLM which will be used in the data interpretation. CF asked if the data will be in spread sheets by mid September, and if so, how long interpretation would take. LC said that an outline

of the report should be available by the next meeting of the TRC.

13. KK then gave an overview of the status of the modeling effort. He had focused on two things. The first was the cross sectional model that goes through the collection ditch. This was done to establish the sensitivity of the model to the geometry of the collection ditch. If the model is very sensitive to this geometry, then it will be important to measure the ditches in detail. This cross sectional model was extended to the east and a variety of ditch geometries was used. The result of the sensitivity analysis was that the model is not sensitive to ditch geometry. Flow did not change more than 3% for all the different geometries tested. This is because of the permeability used. KK then reduced the permeability by a factor of five and again the ditch geometry did not create a significant difference in flow. Therefore precise measurements of the ditch system are not needed.

14. The second cross section modeled was a long one from the alluvial fan aquifer, across the salt, through the collection ditch, to the highway. This is also a thick cross section extending to a depth of 754 feet. This cross section was prepared to see the interaction between the aquifers. They had trouble getting a steady-state solution for this cross section because of the density contrast of the fluids. There is slow convergence and a lot of time steps need to be taken which increases computational time. The fresh water is dumping out of the bottom of the model (754 feet). There is a saline nose developing toward the alluvial fan from the basin fill. CF and KK discussed the desirability of specifying flux in the model as opposed to specifying water levels.

15. LC then requested that the TRC consider the desirability of preparing two reports for this study. LC suggested that it may be appropriate for two reports to be prepared. The first report would be a typical technical report. The second would be more of an executive summary, perhaps even a pamphlet, that would be prepared for general audiences. LC requested input on this idea.

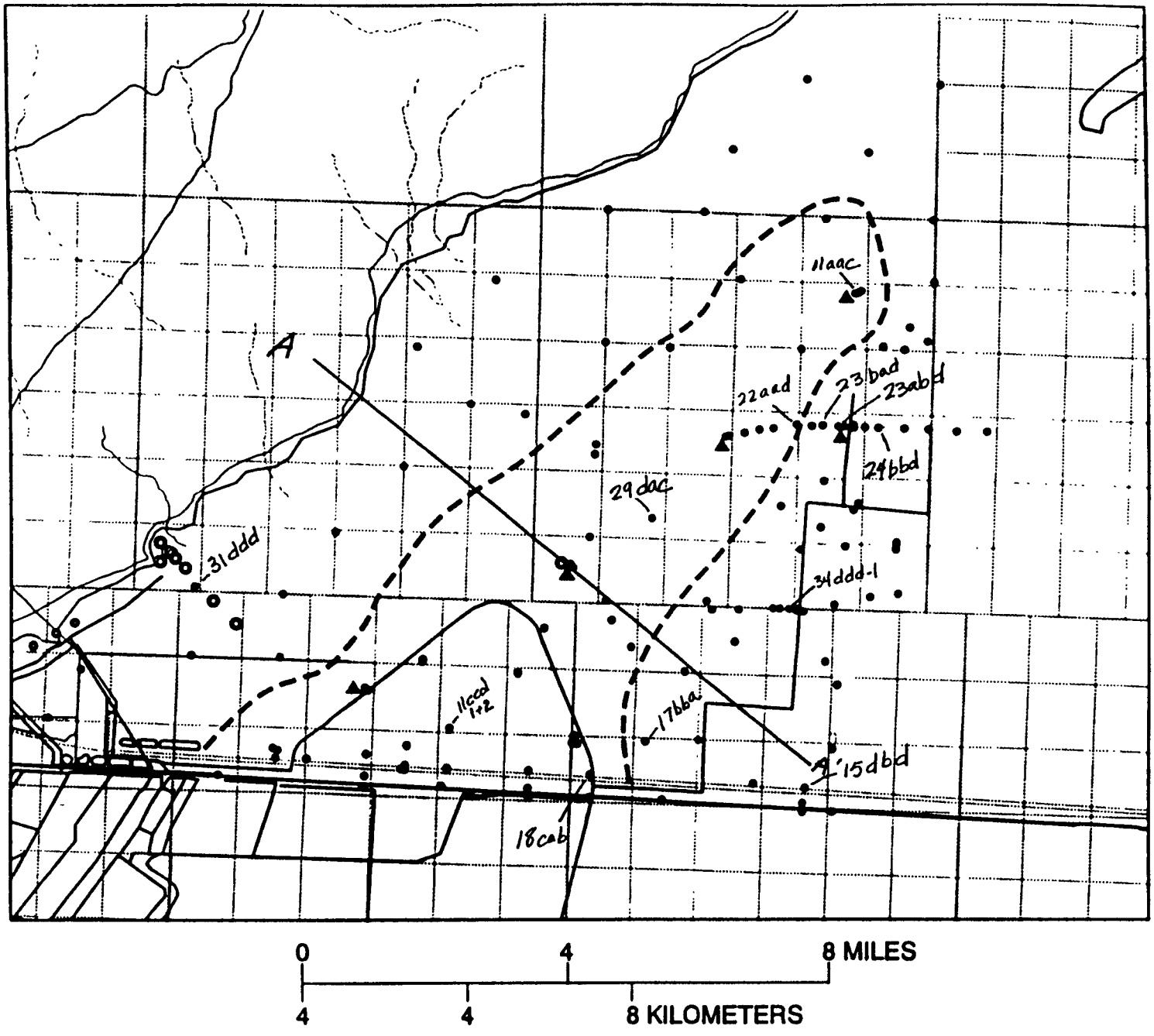
16. At 12:00 the meeting adjourned. It was decided that the next meeting would be held on October 20. KK may develop a conflict. If this were to happen then it was decided to have November 15 be the alternative.

CHEMICAL CONCENTRATIONS OF END-MEMBER SAMPLES

Site	Date	pH	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	Cl (mg/L)	SO4 (mg/L)
SW Pond	1-21-93	6.4	1,100.	130.	100,000.	400.	160,000.	2800.
(B-1-17)31acc-3	8-25-92	--	1,000.	4,600.	94,000.	8,100.	150,000.	8,000.

Site	B (ug/L)	Sr (ug/L)	Li (ug/L)	DS (mg/L)	Br (mg/L)	H-2/H-1	O-18/O-16
SW Pond	<10.	12,000.	1,100.	272,000.	2.5	-143.0	-19.73
(B-1-17)31acc-3	9,100.	29,000.	49,000.	274,000.	28.0	-56.50	-4.15

PROVISIONAL DATA



Hydrologic data sites - locations approximate

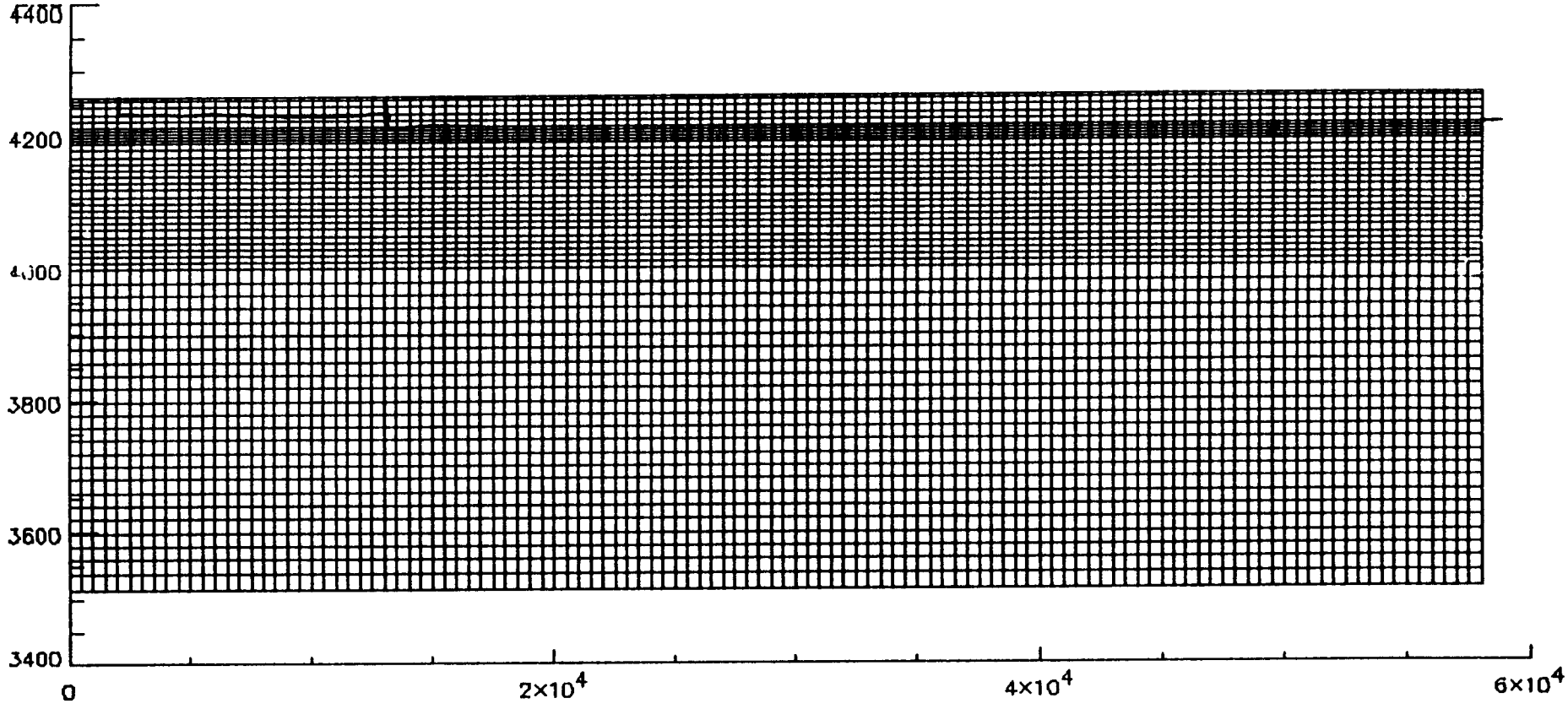
A ——— A' -- Line for deep cross-sectional model.

CHANGE IN POTASSIUM CONCENTRATION AT SELECTED WELLS

	DATE	SP. GR.	KCl %	K (mg/L)
	9/24/76	1.187	1.20	7,500
(B-1-17)11aac-1	5/19/81	1.201	0.62	3,900
	8/11/92	1.191	1.17	7,300
	7/31/65	1.202	1.19	
	10/465	1.202	1.23	
	7/18/66	1.201	1.10	
	8/23/66	1.200	1.23	
(B-1-17)22aad-1	10/10/66	1.200	1.27	
	7/1/67	1.200	1.06	
	9/9/67	1.199	1.14	
	9/23/76	1.194	1.26	7,900
	10/11/77	1.195	1.28	8,000
	10/2/78	1.195	1.48	9,300
	8/11/92	1.198	1.13	7,100
	7/31/65	1.205	1.11	
(B-1-17)23abd-1	10/4/65	1.202	1.15	
	8/11/92	1.198	0.75	
(B-1-17)23bad-2	11/9/65	1.195	1.07	
	8/11/92	1.195	1.08	
	6/18/65	1.204	1.48	
(B-1-17)24bbd-1	7/18/66	1.199	1.04	
	9/23/76	1.129	0.44	2,600
	8/12/92	1.190	1.09	6,800
	9/24/76	1.197	1.53	9,600
(B-1-17)29dac-1	10/11/77	1.198	1.46	9,200
	10/2/78	1.200	1.75	11,000
	8/25/92	1.198	1.59	10,000

PROVISIONAL DATA

	DATE	SP. GR.	KCl %	K (mg/L)
	7/30/65	1.194	1.17	
	9/30/65	1.195	1.20	
(B-1-17)34ddd-1	7/18/66	1.190	1.13	
	8/23/66	1.200	1.26	
	10/10/66	1.199	1.24	
	5/21/81	1.213	0.60	4,000
	8/25/92	1.186	1.22	7,600
(B-1-18)31ddd-1	9/22/76	1.049	0.27	1,500
	8/18/92	1.062	0.31	1,700
(C-1-17)15dbd-1	5/21/81	1.194	0.73	4,600
	8/26/92	1.173	0.70	4,300
	9/23/76	1.196	1.47	9,200
(C-1-17)17bba-1	5/22/81	1.205	1.27	8,000
	8/25/92	1.192	1.54	9,600
(C-1-17)18cab-1	5/22/81	1.205	1.22	7,700
	8/26/92	1.195	1.52	9,500
(C-1-18)11ccd-1	9/27/76	1.189	0.38	2,400
	8/26/92	1.200	0.73	4,600
(C-1-18)11ccd-2	9/27/76	1.202	0.46	2,900
	8/26/92	1.201	1.25	7,900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3600
3400
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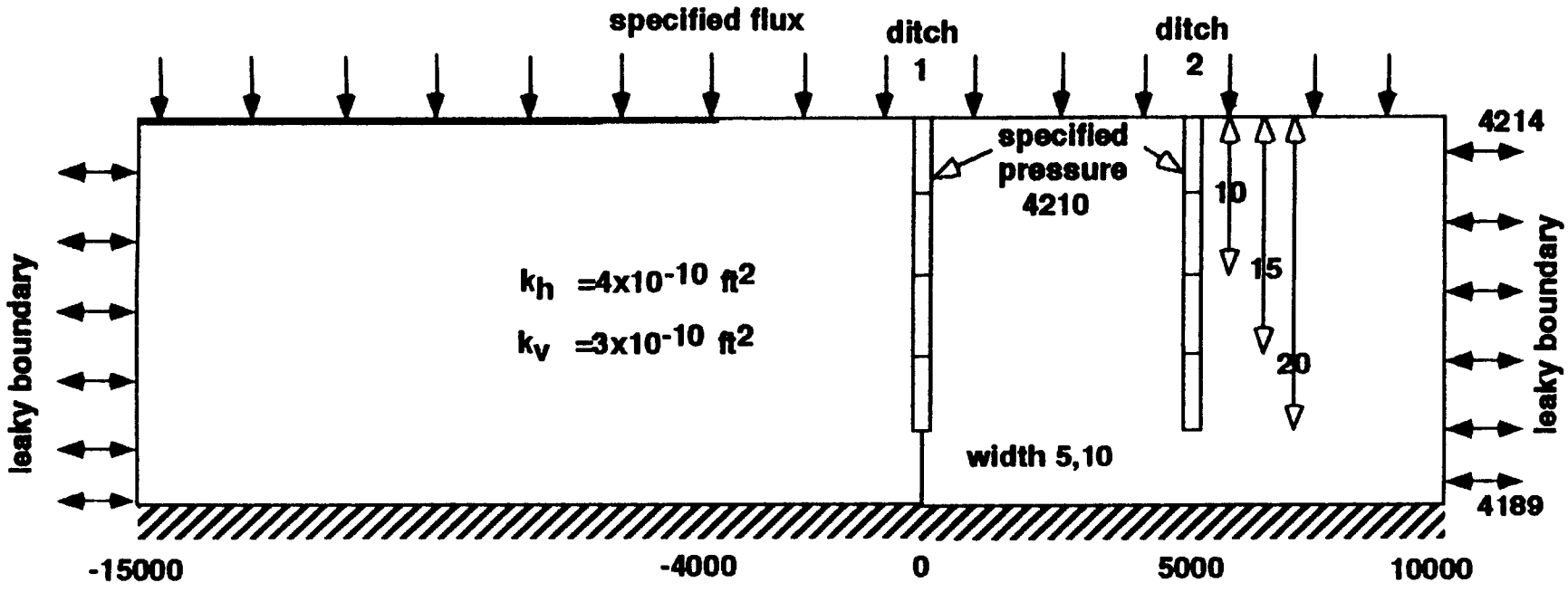
6×10^4


specified flux
ditch 1
ditch 2
4214
specified pressure 4210
10
15
20
leaky boundary
k_h =4x10^{-10} ft^2
k_v =3x10^{-10} ft^2
width 5,10
leaky boundary
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-15000
-4000
0
5000
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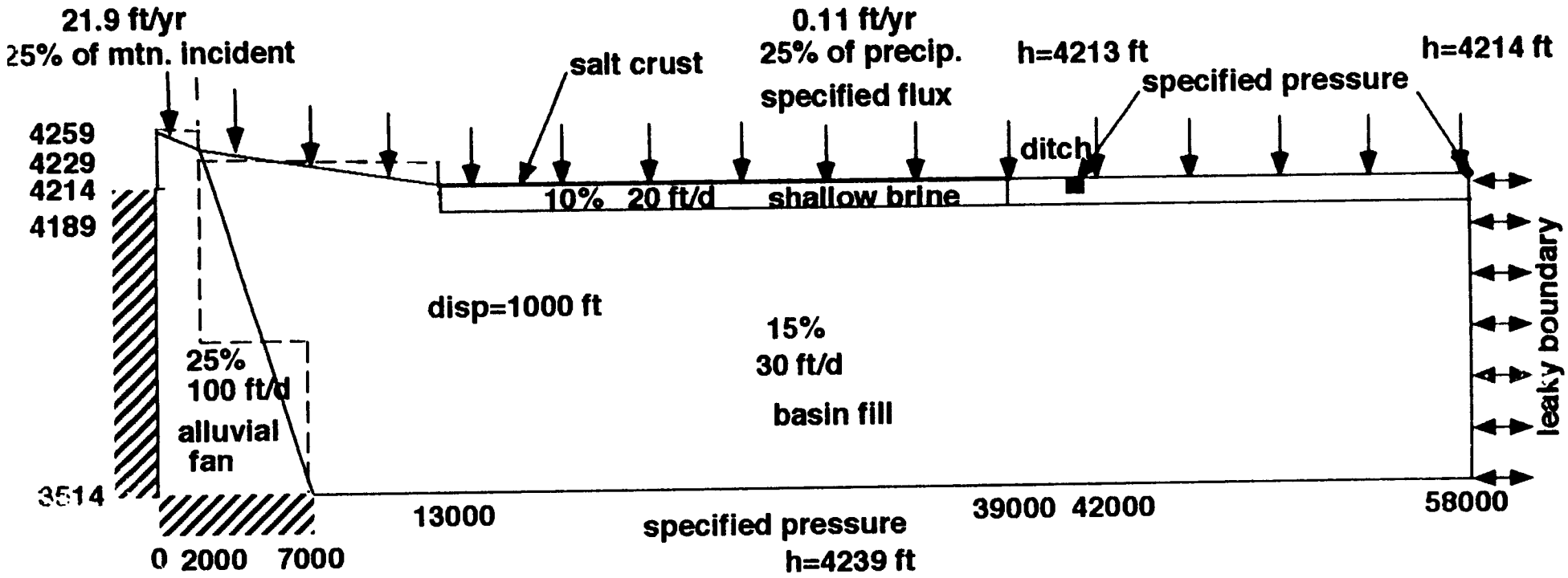
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25% of mtn. incident
salt crust
0.11 ft/yr
25% of precip.
specified flux
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4214
4189
ditch
10% 20 ft/d shallow brine
disp=1000 ft
15%
30 ft/d
basin fill
25%
100 ft/d
alluvial
fan
leaky boundary
3514
0 2000 7000
13000
specified pressure
h=4239 ft
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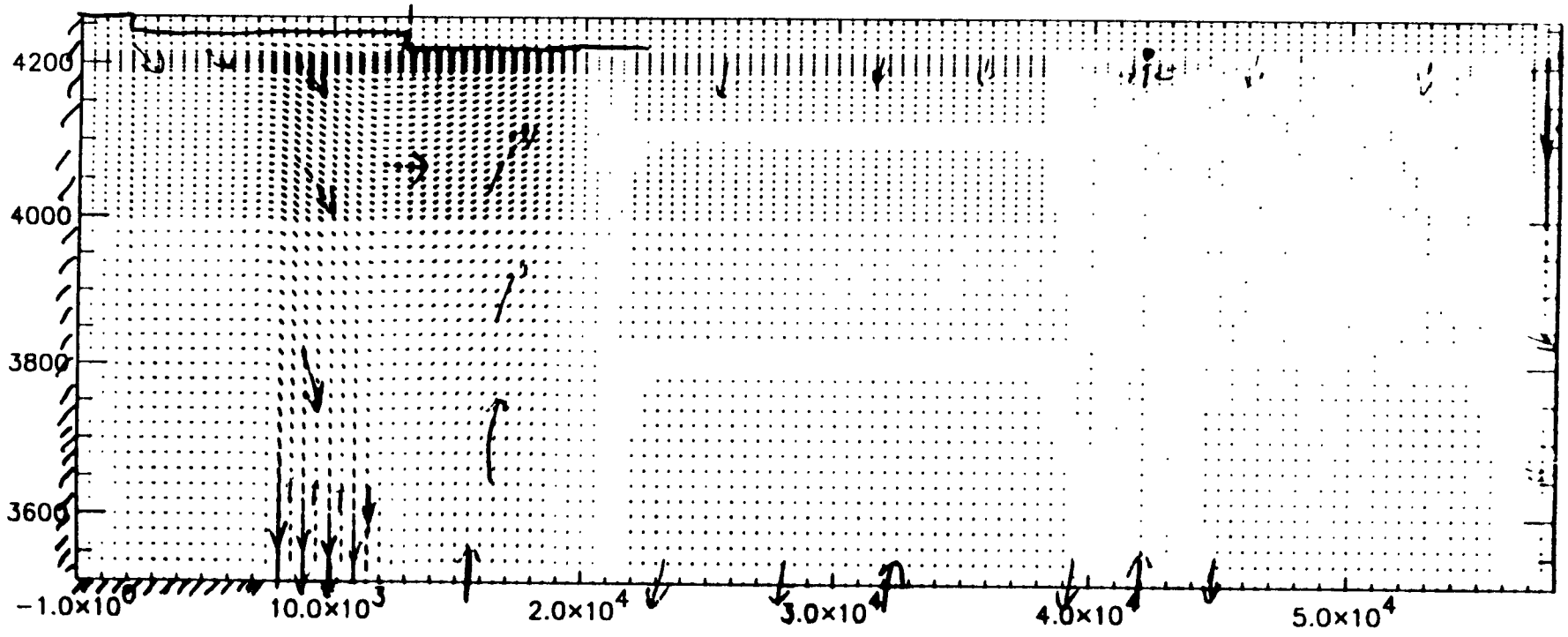
58000


4200
4000
3800
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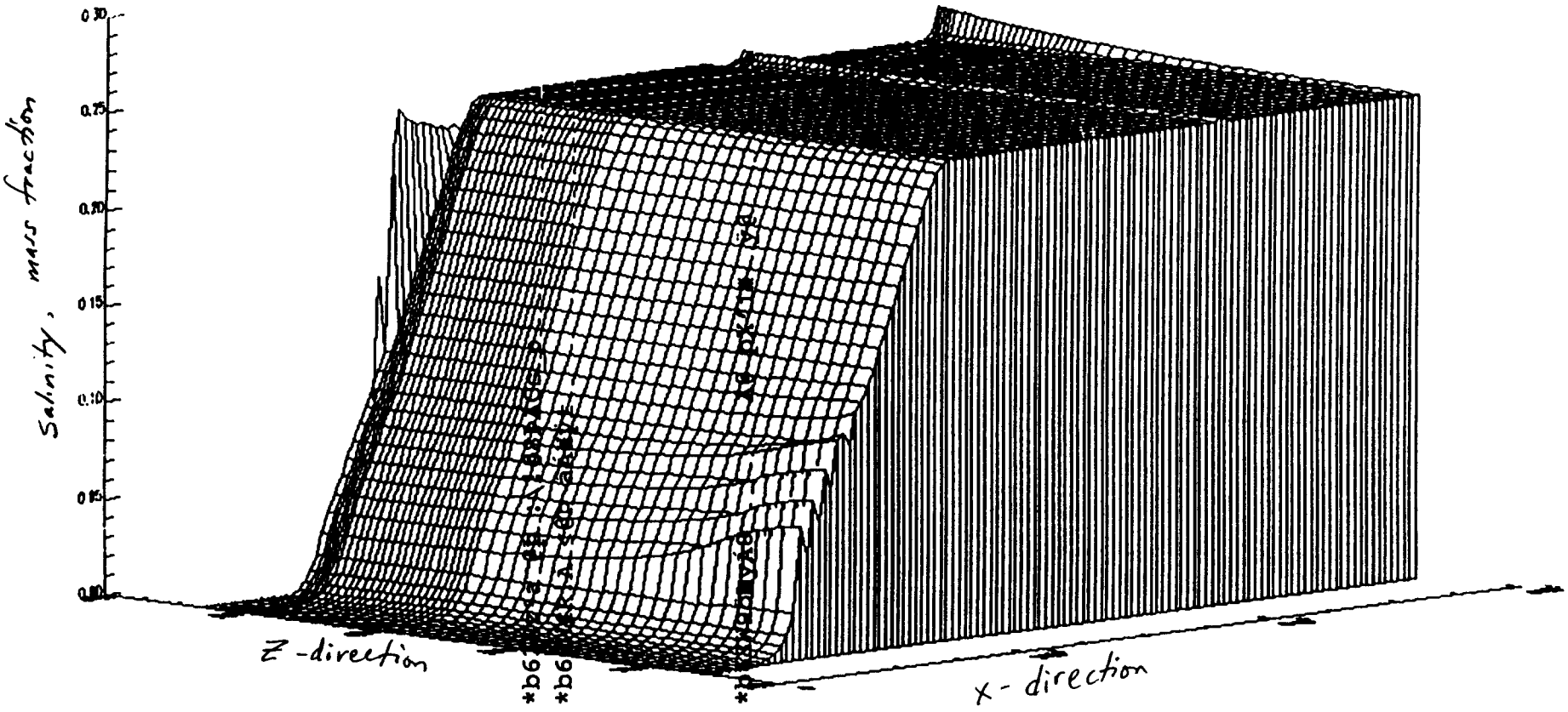
10.0×10^3
2.0×10^4
3.0×10^4
4.0×10^4
5.0×10^4


Salinity, mass fraction
0.30
0.25
0.20
0.15
0.10
0.05
0.00
Z-direction
X-direction

Redistribution Of Salt By Pond Migration,
Bonneville Salt Flats, Western Utah

Problem: The BLM is concerned that a potentially significant form of salt loss from the Bonneville Salt Flats is by wind-driven surface ponds during winter months. These surface ponds, which are composed of brine, can be blown over the area influenced by the brine-collection ditches and thus, infiltrate into the subsurface. Also, during spring months, salt can be deposited in this same area by evaporation of the surface ponds and precipitation of salt on the mud-flat surface. This salt could then be dissolved by direct rainfall and subsequently infiltrate into the subsurface. The BLM would like to know the quantity of salt transported by this mechanism and to have a method by which this process could be monitored in the future.

Hydrologic Processes: The surface ponds form in the late fall, most likely, as a result of the rising water table. When evaporation ceases or becomes negligible, brine from the shallow-brine aquifer gradually accumulates on the surface of the salt crust where it can be transported by wind. There is no evidence to support the concept that the ponds are formed by precipitation either as direct rainfall on the surface or as surface runoff from the Silver Island Mountains. However, direct precipitation will add to the volume of brine in the ponds and can dilute the brines to the point where dissolution of salt might occur.

With this concept of pond formation in mind, the question may arise as to what area of the salt crust does the brine originate, or what percentage of the brine is derived from private or leased property? This can be estimated by defining the overall area that might contribute brine to the surface ponds and then determine what percentage of this area is private or leased. The contributing area can be defined by delineating the area where the water table is within a specified distance below land surface during the fall before ponds begin to form. The percentage is then applied to the volume of the surface ponds to determine the amount of salt that might derived from private or leased property.

During the winter months, the surface ponds are moved in the direction of the prevailing winds. These ponds may move within a matter of a few hours with changing wind direction. With the possible rapid movement of surface ponds, tracking the movement of the ponds is not feasible or practical.

Priorities
Salt Density – Do by BLM next
Pond Migration – Part of ESWR studies
Pilot Valley – " "

The two methods of salt deposition within the area of influence of the collection ditches, described above, should be the primary emphasis rather than merely tracking the migration of ponds. Infiltration rates need to be estimated for the carbonate mud between the salt crust and the collection ditches. By knowing the infiltration rate and estimating the length of time surface ponds are in this area, the quantity of brine infiltrating into the shallow-brine aquifer can be estimated. Turk and others (1973, p. 73) estimated infiltration for the carbonate muds to be 0.4 to 1.4 ft/d. Lines (1979, p. 85) stated that even the infiltration rate of 0.4 ft/d is probably high. At best, Lines thought that infiltration rates are probably 10 percent of those for the salt crust, thus ranging, at most, from 0.25 to 0.4 ft/d. On the basis of these rates, Lines (1979, p. 86) estimated that 2,000 acre-ft infiltrated into the carbonate mud within the area of influence of the collection ditches. Tritium values from brine collected from six wells along the north line of wells between the salt crust and the collection ditch suggest that a negligible quantity of brine from the surface ponds infiltrates through the carbonate mud into the shallow-brine aquifer (see figure). Additional sampling and tritium analyses are needed to define this relation.

The other method of salt transport into the area of influence of the collection ditches is by precipitation of salt onto the carbonate-mud surface upon evaporation of ponds in the spring and early summer. An estimate of this quantity of salt might be derived by examining satellite images in the fall, just prior to pond formation, and in early summer after the ponds have disappeared and a new crust remains.

Approach: Infiltration of brine from surface ponds, if it is occurring, would be the more complex of the two processes. Evidence from tritium analyses, mentioned previously, suggests that infiltration may not be a significant process. To verify this hypothesis, three additional, hand-augered wells need to be installed adjacent to existing deeper wells on the east end of the north line of wells (see figure). These wells will be completed at a depth such only the water-table surface will sampled. The brine will be analyzed for tritium and compared to values obtained for brine from the deeper, adjacent wells. If the new tritium values are similar, then the hypothesis for no significant infiltration in this area would be substantiated. Additional tritium samples would have to be collected at other locations between the salt crust and the collection ditch in order to verify the lack of infiltration throughout the area of surface ponds.

If the new tritium values range from 15 to 25, then infiltration would appear to be significant process for placing salt into a pathway for migration to the collection ditch. As a result, an estimate for infiltration is neccessary for calculating total infiltration during winter months. One method for estimating infiltration rates would be to collect cores for geotechnical analyses. By determing the vertical profile for specific retention and using the VS2D model, the rate of infiltration can be estimated. The disadvantage with this method is the inability to compensate for the retarded infiltration after the surface clays have expanded as a result of hydration of the clay matrix.

An alternative method would be to measure actual infiltration in situ. This could be accomplished by an actual field experiment in which brine is placed at the surface and its infiltration is measured by nested tensiometers; however, most field methods of this type, such as the instantaneous profile method, allow the sample water to infiltrate fully and the water content of the soil is measured by the tensiometers as the water moves downward. As with the previous method, the retardation at the surface is included. Therefore, the field method selected or developed must be able to compensate or measure this possible retardation.

Estimating the quantity of salt deposited on the surface upon pond evaporation in the spring would require knowing the areal extent of the salt crust in the fall prior to pond formation and knowing the areal extent of the salt crust after pond evaporation. Any increase in the areal extent of the salt crust between the main part of the salt crust and the collection ditches to the east could be attributed to pond migration assuming all the new salt deposited is from the ponds and not from evaporation of brine within the playa mud. By assuming an average thickness for the newly deposited salt based on field measurements, the volume can be estimated.

The changing areal extent of the salt crust is a dynamic process that depends largely on short and long-term climatic changes. Any estimates of salt transport by surface ponds are only approximations that involve snapshots in time and many simplifying assumptions. These estimates should only be used to determine the relative significance of this process in the overall salt budget for the Bonneville Salt Flats.

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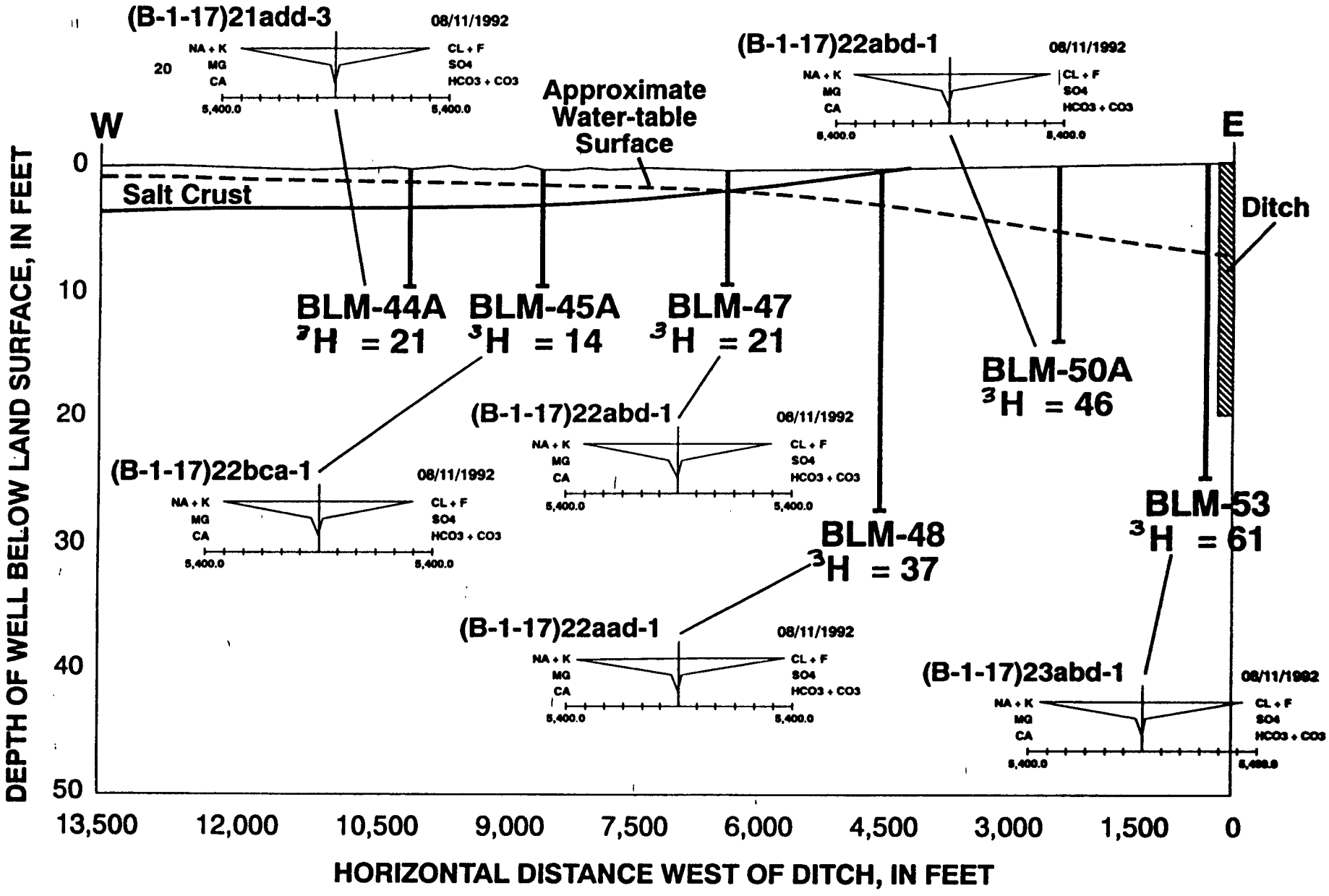
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DEPTH OF WELL BELOW LAND SURFACE, IN FEET
HORIZONTAL DISTANCE WEST OF DITCH, IN FEET

Methods For Measuring Density Of Salt Crust,
Bonneville Salt Flats, Western Utah

Problem: The Technical Review Committee (TRC) has requested that the U.S. Geological Survey (USGS) propose one or more methods for measuring the density and stratigraphy of the salt crust taking into consideration spatial and temporal variations. The TRC believes that a density profile through the various layers of the salt crust is an important component of the study. The density values can then be used to convert the volume of salt loss to units of weight.

Methodology: There are basically two approaches for measuring density of the salt crust, extraction of undisturbed samples for lab analysis or measuring in situ. Because of the noncohesive nature of the bulk of the salt crust, the usual coring procedures used during drilling operations were not successful in collecting complete, undisturbed cores of the salt crust. Therefore, to collect undisturbed samples of the salt crust, a more invasive method would be needed where horizontal samples could be collected. This would require cutting large holes (approximately 1 square foot or larger) in the crust in order to gain enough access to collect horizontal samples throughout the vertical profile. The collection of horizontal samples appears to be the only method that would insure relatively undisturbed samples. These samples could then be measured for bulk density by extracting the intergranular brine and then drying and weighing. The necessity for extracting the intergranular brine would be to reduce the error resulting from the precipitation of salt during the drying process. An alternative method would be to extract the intergranular brine and then impregnate the pore space with a pigmented resin. A photograph of the impregnated surface would be taken and the area of the pigmented resin would be determined. By assuming a value for the density of halite, the density of the sample can be estimated based on the area of pore spaces. This method might be less accurate because the determination involves only a flat surface rather than a volume.

The advantages to the sample-extraction method described above would be the small expense of the equipment involved, the ability to determine the existance of significant silt layers if present, and the use of simple methods for determinig density. The disadvantages would include the necessity for cutting large holes in the salt crust and the large time requirement involved to obtain a single vertical density profile. Because of these disadvantages, it would not be feasible to have a large number of data points for spatial variation.

There are two possible methods for determining density in situ. One method would generate an average density for the upper 12 inches of the crust and the other would generate a vertical density profile. The first method would use an instrument designed to measure highway road-bed compaction. This instrument could be used readily at numerous sites. An one-inch diameter hole would be drilled 12 inches into the crust. A probe with a cesium-137 source would be placed into the borehole. The detector in a box at the surface generates an average bulk density for the salt from the surface to a depth of 12 inches. The advantage to this method is the ability to make numerous density measurements thus, insuring good spatial and temporal representations. The disadvantage of this method is the inability to obtain a vertical profile. Only a single average value for the upper 12 inches would be obtained and that value would be applied to the entire crust at locations where the crust is thinner and thicker than 12 inches. At locations where the dense upper salt crust exists, the single average value would incorporate the dense, fine-grained salt and the less dense, coarse salt.

The second in situ method would involve the use of gamma-gamma (density) logging techniques. Similar to the surface density instrument mentioned above, this tool also uses a cesium-137 source. The tool would be lowered down the borehole, thus producing a vertical density profile. Because of the short interval to be logged, less than 5 feet, a short tool must be used, thus reducing the average radius of penetration. For this reason, existing shallow wells might not be usable because of the PVC casing and grout in the borehole. If the existing wells are unusable, then new access holes would need to be drilled. This is a simplified description of the method that does not mention the need for detailed calibration and standardization procedures.

The advantages of this method include the generation of a vertical density profile and the ability to obtain data at several sites. The disadvantage involves the probable need to drill new logging access holes.

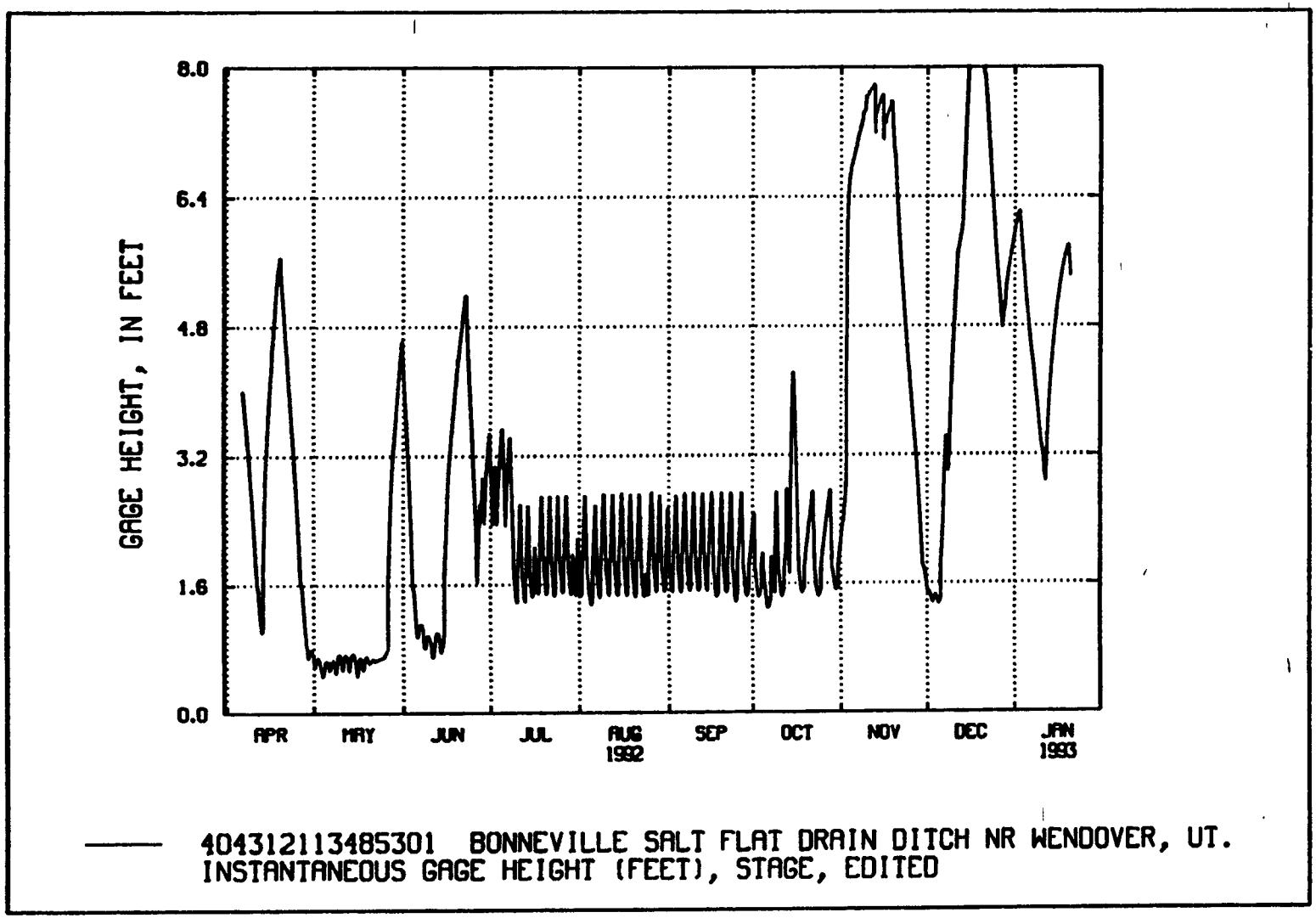
Both of the in situ methods mentioned above would require the acquisition of the necessary instrumentation and the proper operating license. The surface density instrument costs approximately $4,500. The cost for gamma-gamma logging equipment were not obtained.

Addendum to progress report for the Technical Review Committee dated February 2, 1993

In the discussion on the comparison of potassium and magnesium values in well fluids and pore fluids, the report stated that the concentrations of potassium and magnesium were higher in the pore fluids than in the well fluids. This is generally true when comparing pore fluids to well fluids from all shallow-brine wells. By taking into consideration the location where each core was obtained, the concentration of potassium and magnesium in the pore fluids is similar to the concentration in the well fluids from adjacent wells.

Even though the concentrations of potassium and magnesium in the pore fluids are similar to the concentrations in well fluids in the vicinity where the cores were collected, diffusion of potassium from the pore fluids might be a possible explanation for the apparently stable potassium distribution in the shallow-brine aquifer from 1976 to 1992.

Additional core sampling of saturated deposits at the margins of the salt crust would be beneficial in order to obtain a better areal distribution of pore fluids. These samples could be obtained by hand-auger techniques. From the additional information, more comprehensive comparisons can be made on the areal distribution of potassium and magnesium in both well fluids and pore fluids.



PROVISIONAL DATA

Minutes of the Technical Review Committee
Meeting of February 2, 1993
Recorded by Philip Allard

Attendance:

Committee Members:
Paul Anderson (PA)
Craig Forster (CF)
Wally Gwynn (WG)
Jim Kohler (JK)
Hugh Coltharp (HC)
Stanley Plaiser (SP)

BLM Representatives:
Phil Allard (PhA)
Deane Zeller (DZ)
Mike Ford (MF)
Cheryl Martinez (CM)

U.S.G.S. Representatives:
Lee Case (LC)
Jim Mason (JM)
Geoff Freethey (GF)
Joe Gates (JG)
Ken Kippe (KK)

Preliminary Meeting, USGS Representatives Not Present:

A preliminary meeting was held beginning at 9:00 am. in the BLM conference room at the Salt Lake District Office. The representatives of the U.S.G.S. were not in attendance at the preliminary meeting.

1. Minutes from the 11/3/92 meeting were presented. PA said there were a couple of typos. TN said that on item five on page four the words "basal part" in the second sentence should be changed to middle portion". With this change, PA moved that the minutes be accepted as modified CF seconded and the motion passed.

2. PA introduced the need to elect officers for the committee for the new year. SP, DN, and WG were not yet present. Therefore the election was table until the post meeting.

3. PA then discussed the USGS materials. PA said that he was pleased with what had been submitted. CF then said that he was pleased but had questions for the USGS.

4. CF was puzzled by the potentiometric surface map, particularly the low on the edge of the area near the Silver Island Mountains. CF wondered about the conceptual model used by the USGS to draw the contours. None of the wells in the pump test seemed to be used in

the map. PA said that he was not clear about how the density of the fluid effected the contours. CF said that inferring the direction of flow from the contours of the potentiometric surface was not strictly appropriate when looking at systems where the densities of the fluid varied. The real way to interpret the flow will be through the solute transport modeling. With density correction there is an accentuation of the mound in the potentiometric surface in the center of the salt crust. CF stated that there is a potential difficulty with the map if there is variation in the depth of the wells used for constructing the map. PA said he assumed they were dealing with the shallow brine aquifer. WG said that is what they were charged to study.

5. PA said that he was pleased that the USGS was looking at the base of the computer model. He indicated that he was concerned that an impermeable lower boundary to the system ma be unrealistic.

6. PA asked WG about the Kl data. PA thought it was interesting that some aloes had increased since the Lines study. PA also though it was interesting that there was a difference in values between the values for well fluids and for pore fluids. WG said that it is not significant to look at Kl in isolation from other components of the brine. It is important that brine analyses report cation-anion balance. PA asked if data by dry weight percent was an appropriate method for reporting the data.

7. CF said he was curious about the pond migration study changes proposed. CF said that on the surface it looks like a reasonable approach but wondered if others had comments. PA said that he thought it was reasonable. CF said the most useful component would be through the use of the tritium data. CF said that you needed helium (He) data as well. Combined He and tritium data can give you absolute age dating in the years to tens of years range. PA asked if there is ambiguity in the tritium data. CF said that there can be. TN asked how easy is i to measure for He. CF said that it was straight forward but does cost a bit, several hundred dollars per sample. Also it is research based and is not commercially available. CF said that a full study would run $5,000 to $10,000 for the analyses.

8. PA stated that he hoped the USGS reports on their schedule and their budget. SP said that it looks like they are getting close to their deadline for completion.

9. TN asked about the salt crust bulk density issue. He wondered if there was anything in the published literature which addressed this issue. JK said that really isn't very much. SP said that he assumed that he assumed from the USGS write-up that they were discussing a nuclear density gauge. SP said that his experience indicated that you can get a profile from the tool, but it could only go 12 inches deep. The detector is at the surface and the probe is lowered into the ground, but can be stopped at a variety

of depths.

Main Meeting, USGS Representatives Present:

1. PA welcomed the USGS representatives. He thanked them for the information that they had provided and invited JM to proceed. JM said that progress included contouring a set of water level measurements. There are data points that are missing from the data set because they do not yet have elevation control. The map seems similar to the one produced by Lines which would indicate that the system is in equilibrium even though there is seasonal variation. GF said that the density correction was about 0.25 feet on the average. In order to understand vertical relationships you needed to consider density and the gravity component of the velocity vector rather than look at the system from the point of view of fresh water head equivalent. SP asked what was the density that was used for corrections. GF said that a specific gravity of 1.18 was used. PA asked what had Lines done. JM said that he reported both uncorrected and normalized to fresh water head equivalent.

2. CF asked if JM had an explanation as to why the contours declined to the north west. JM said that Lines attributed it to the pumping the wells in the alluvial fan aquifer. The wells in production are quite a distance to the south and west. Pumping would have to propagate tens of miles to the northeast which is strange. CF asked if resolving this is a significant problem. JM said that it is important to understand this issue. They tried to get a well in near the weather station on the alluvial fan, but drilling conditions did not allow this fall. The area where the contours start to decline is still in the mud flats. CF suggested that vegetation may be sufficient to provide a draw down to the system; perhaps the draw down here is a result of going from unvegetated to vegetated conditions. This would be a localized draw down effect. JM suggested that winter/early spring data would not show this same draw down, and the data they contoured so far is for the June-July water level measurements. CF asked is the southeast draw down was related to the ditches. JM said yes. SP asked if the data were collected at the same time and how were they corrected. JM said that the data were collected in June and July and were all corrected to a specific gravity of 1.18, so the water level of water fresher than this was lowered and the water level of water more briny than 1.18 was raised. Water level data were collected in March-April '92, June-July '92 and October '92. The last two sample runs are the most complete because additional wells were installed during the spring and summer and are not included in the first sampling run. Complete elevation data are not yet available so the spring and fall data have not been contoured.

3. SP asked about the piezometers that are normal to I-80. JM said that they have been installed and water levels have been measured; however, they do not yet have elevation data so the

analysis of head differences across I-80 has not yet been completed. JM said that they are trying to correct this problem. He said that he had met with Don Buhler of the BLM and his staff is going to try and get out to do the measurements in late February. JM has made arrangements for Pam Muir to go with the surveyors to ensure that all of the new wells are surveyed.

4. PA asked if the potentiometric surface map was on the shallow brine aquifer. JM said that it includes wells that are 25 feet or less deep. PA then asked if the screened interval was in that 25 feet. JM said yes the screened interval was within that 25 feet, implying that the screen was not necessarily at the very same depth in each hole.

5. PA asked about the vertical component of the system. JM said that they still lacked the elevation data needed to complete this analysis. PA said that intuitively he could see up welling in the center of the basin with flow across the surface of the mud and then flow into fractures in the alluvial fan system. this could explain the flow toward the alluvial fan implied by the potentiometric surface map. PA illustrated this on the board. PA suggested that if the fractures are only in the surface clays then you might get this kind of circulation. JM said that he didn't think that this was happening because the coarse material in the alluvial fan was encountered deep in the hole (about 200 feet below the surface) and because the surface elevation was rising along the alluvial fan. JM said that the fracture dominated system also appears to be confined to the center of the playa and there is an extensive area of unfractured mud between the center of the playa and the alluvial fan. The coarse material in the alluvial fan is also very close to the Silver Island Mountains.

6. JM then passed around his working copy of the cross section from the study area. He had attached stiff diagrams which illustrate the chemical analysis of the waters to the cross section. JM said that he was surprised to find all of the waters to be of the same chemical character; dominantly NaCl. He would have expected the water near the alluvial fan to have a strong sulfate and carbonate contribution but has not found this to be so. He had also plotted oxygen and deuterium values on the cross section. The oxygen and deuterium data indicate that from the mountain front to the berm southeast of the pump test well you have meteoric water and from the berm to the mud flats you have evaporative water. He would have expected carbonate and sulfate type waters near the alluvial fan but instead you have NaCl dominated water throughout. JM speculates that you are not having flow from the mud flat to the fan because of this and suggested that you are having propagation along the fan because of pumping. LC said that it would be more cost effective to explore this issue with modeling than it would be with additional drilling.

7. CF asked if it would be appropriate to look at the vertical

component with nested piezometers in the center of the 4214 contour. JM said that they have a nested set with 7 intervals monitored. The seven wells go from 2 feet to 500 feet. It is an important component of the study. JM has a working hypothesis that there is not a vertical component that would provide recharge of the system from depth.

8. JM said that he had gotten some additional data since the progress report on pore fluids and well fluids. He wrote an addendum to the quarterly report and passed it out to the group. When you look at the location of the samples and the contours the similarity of the pore fluids to the well fluids is very close, so the write-up in the initial progress report is somewhat misleading. The pore fluids could be a possible source of potassium, slowly releasing potassium to the active aquifer. This could explain the similarity between the Kl contours today and those reported by Lines. The contour map in the report is of well fluids. the pore fluids range in potassium content from 1% to 1.5% by weight percent. One core adjacent to the Salduro Loop shows pore fluids depleted in comparison to the well fluids. JG said that this lessens the evidence to support a dual fluid model (pore fluids/fracture fluids). CF asked if there are significant differences from Lines. JM said that there were in only two locations. CF asked if they get consistent cation/anion balance in there analyses. JM said that he has had some problems with the lab. CF asked if the Lines data are credible can we then compare the data sets to make some conclusions as to long term changes in the system. JM said that you have to be very careful because the basic system is quite similar from one point in time to another. LC said that if they are having problems with cation/anion balances he will call the lab. LC said that the lab doesn't routinely run samples that are this concentrated so they have had some problems. LC said that they are using the same lab as Lines so that they can make comparisons in time and not have to account for any differences because of differences in labs.

9. JM said they have sent the salt cores to Reston and Reston has forwarded them to SUNY Binghamton for a study of fluid inclusions, but no results are yet available.

10. JM said that they had important work scheduled for the near future which includes water level measurements in the winter, but access continues to be a problem. The deepest water is at the end of the access road and is now about 18" deep. Four wheelers are the only way that they can get around, but hypothermic conditions are a safety concern. They plan to continue monitoring the pump on the production ditch. JM said that they (Reilly Industries) have been pumping periodically this winter, but they don't generally do this. JM asked SP if he knew why this was happening. SP said that he didn't know but also thought that they didn't normally pump during the winter. JM said that this could lead to questions in the simulation. They know fixed conditions during production

months but there is no real certainty as to what they are doing during the winter months.

11. JM said that data supplied by Reilly industries on withdrawals from the production ditch is considerably higher than what USGS measured with their gauge. SP said that he was working on more specific data and will provide it. SP said that he was working on more specific data and will provide it. PA asked what the relationship with Reilly Industries was like. JM said that he needs to be more specific with any future requests for data. JM asked for discharge data from the ditch. He received one discharge number for each month. He suspects that they measure weekly and didn't expect an aggregated number. LC asked SP if Reilly if the Reilly folks could call JM regarding any future data requests. SP said that he will do what he can but reported that he has experienced similar problems from time to time. JM said that the data is confidential so they can use it in their model but won't be able to publish the data to document their model. LC said that they will need to address this issue at the time of the draft. LC said that it will be difficult to get a blanket release from Reilly, but they may be able to get a release once Reilly gets a chance to see the specifics. PA suggested that we start working on this issue now. LC said that he didn't think that the USGS should undertake this unilaterally at this time, but suggested that the committee might want to work on it. JM said he has never used any K1 values. Volume data is the only thing that the USGS is interested in at this time. TN said the crucial thing is that you focus this request (data release) to data that are important to the study or crucial to it rather than have it as a general or blanket request. JM asked about collecting data from the south ditch (on private property) and reported that Clarence Prentice said no. LC said that they could get a letter together to list the kind of data that they want to use in publication and then get that letter to the BLM for discussion with Reilly.

12. JM said they still had 4 issues to discuss, vertical gradients, salt crust bulk density, salt redistribution from ponds and computer modeling. CF asked if we should schedule another meeting. JM said that the salt density issue and pond migration issue relate to decisions which need to be taken in the near future and are key. CF sid that scheduling and budget are important issues. LC sid that it is most important to him to have KK present his material because he is on per diem from Denver. PA said lets take care of that then. KK then presented a status report on vertical gradients and the status of the computer modeling.

13. KK started with a discussion of vertical gradient. Gravity component of vertical head is a confusing topic for some people. In systems that don not have variable density, water level maps can show the direction of flow. Variable density fluids don't react in the same way. It is important to consider the basic forces involved. Here KK gave a credit to the work of Hubbard. There are

two components of the force involved in flow. There is the pressure component and the gravity component. When a fluid is in equilibrium pressure and gravity are in balance and no movement takes place. In a dynamic situation the downward force of gravity and a tilt to the pressure field give a net vector that describes the flow of the material by rate and direction (force vector). In an isotropic medium force vector and direction of flow are parallel. When two fluids of different densities are in the same system each fluid will have a different force vector because the gravity component of the equation will be different for each fluid. Although it can be assumed that the gravitational field is constant for both fluids, the density of the fluid is considered when determining the gravity component used in determining the force vector. KK discussed force vectors in detail to show how correction of density to fresh water head works mathematically. He said that sometimes it is more convenient to correct to average density than freshwater head. For simplicity he said that he disregarded any difference in viscosity between salt and fresh water. PA asked about the term H_1, is it the reference head? KK said that you can chose any density you like, you don't need to select fresh water. JM said that the only data you need to collect in the field for this are head and density. However, correction to a standard density doesn't account for changes in velocity if you just map the head. Therefore you can not pick the hydrologic gradient directly off of a potentiometric surface map because it ignores the gravity component of the fluid. CF asked if they look at pressure in the model. KK said that they also look at pressure differences in the model. They are using code that uses pressure differences in the model because of the difficulties inherent in using potentiometric surface maps for gradient determinations.

14. KK then took time to discuss the model. The model has developed since last meeting. KK said that he was now at the second generation. KK as removed the NW corner where the Silver Island Mountains occur and has mapped in the production ditches more realistically. They changed the boundaries slightly using a specified flux at the NE border and specified pressures on the other boundaries. They are still working with a single density fluid so they can calibrate the boundaries. The are still assuming no flow across the base of the modeled area. The model is a node based rather than a cell based model. They have assumed no flow at the boundary with the Silver Island Mountains, but they intend to change this condition as the data interpretation proceeds. They will probably assume leakage from the shallow brine aquifer to the alluvial fan aquifer. They are assuming a net recharge to the system over time, but this may change.

15. CF asked if the tritium data suggest a net recharged system. It can be interpreted several ways at this time. JM said that he wants to look at this in greater detail, including auguring additional shallow wells. CF said that he wants to talk about using Helium data to help in the interpretation of the tritium data.

16. KK said that the model was then run to steady state condition. The results of this run yielded a lot more flow from the ditch than Lines and less out of the south boundary. The largest fluxes are net rainfall in and the ditch out which are about in balance. When looking at the computer generated potentiometric surface map it is apparent that the NW boundary is unrealistic because it differs markedly from observed conditions.At this time the model is having a difficult time maintaining uniform inflow and outflow. Computationally the model is slow taking as much as 30 minutes to run (this depends on the demand for input and output). KK reported that his workstation had been upgraded to run as much as five times faster. High heads on NW boundary can achieve steady state flow by inflow from the east. There is large outflow to the south because of the specified pressure boundary conditions.

17. PA asked about vertical variation of hydraulic conductivity. KK said that he has no data on vertical hydraulic conductivity and takes all of his assumptions from Lines.

18. CF asked if KK wanted to extend the model to the north or to the east. KK said that they have no data to the east, but they could move the model to the east to see if it helps. CF pointed out that there is only one grid block east of the ditches and the math may work better if they move the grid to the east. LC said that they would be doing a sensitivity analysis to see haw sensitive the ditches are to this.

19. There was a discussion of the status of the budget. LC said that he can report the budget based on management category, but it isn't broken down by project component. He said that he would consider the study of the bulk density of the salt crust to be a contract add on. Since no additional funding is available, something in the study would have to be foregone if USGS were required to pick up the bulk density of the salt crust issue.

20. PA then asked about the bulk density issue. PA feels that the TIC is still strongly in favor of collecting data in this area. He said that he was happy with the ideas that USGS submitted. PA said that he felt that a vertical profile of the density was important. JM pointed out that the write-up submitted was simplified and emphasized there is a lot of calibration that would be needed for any geophysical tool used. At this time there is no guarantees that the results of such a study would be sound. JM said that he didn't have an estimate on cost and didn't know what part of the existing study should be dropped. JM said that there may also be temporal variation in density. Seasonal variation may be difficult because there are only two seasons for data collection left. SP had a comment on page two of the proposal. He said that he assumed that JM was discussing a nuclear density gauge. He is concerned about correlating the tool and calibrating the tool. He said that the tool can also measure at variable depths down to 12 inches. JM

said that he understands that that is the case. He passed around a sample of a core of the salt crust. JM said that gama-gama logging may not be able to sample the slurried material effectively and the grout and casing of the wells may effect the results. PhA told LC not to spend time constructing a cost estimate on this study element until he checked with the Contracting Officer. LC agreed to supply the most current budget data to the BLM based on USGS management categories.

21. PA suggested that the group skip to the pond issue. JM said the pond issue has been difficult. JM said that he is looking for a method that wasn't labor intensive so the methodology could be adapted to the long term monitoring of the situation. JM said that he felt that measurement of end point conditions would be most effective. They will be underway with this approach as quickly as they can which may be the end of February. PA said he felt that the USGS was headed in a reasonable direction. SP said that he had a general reaction about quantifying the character of the salt crust as being even more important than the pond migration study. It was suggested tat the Pilot Valley study may be available to fund a salt density study.

At this point the meeting adjourned. Because the agenda was not complete, the TIC decided to reconvene on February 23, 93 at 9:00 am. At this time they plan to discuss the salt density issue, the pond migration study, and conduct an election of officers.